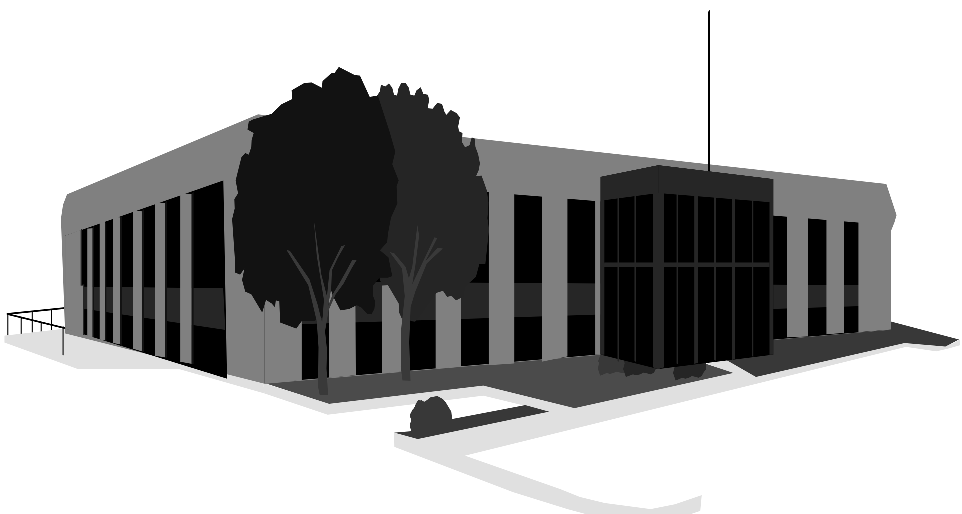
INDOOR AIR QUALITY ASSESSMENT

Franklin Elementary School
2 Cypress Terrace
North Andover, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Mr. Paul Szymanski, Director of Management Support Services for the North Andover School Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Franklin Elementary School in North Andover, Massachusetts.

On June 6, 2002, Cory Holmes, Environmental Analyst for the Emergency Response/Indoor Air Quality Program (ER/IAQ), BEHA, visited the school to conduct an indoor air quality assessment. BEHA staff were accompanied by Joseph Mailloux, school custodian, for portions of the assessment. Mr. Holmes returned to the school on September 19, 2002 to inspect the exterior of modular classrooms.

The school is a single-story brick building constructed in 1958. An addition was built in 1968 and modular classrooms were added in 1993. The school is made up of general classrooms, library, computer lab, cafeteria/auditorium, kitchen, occupational/physical therapy room, music room, art room and office space.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

This school has a student population of 330 and a staff of approximately 40. Tests were taken during normal operations at the school, however a portion of the third grade was away on a field trip, therefore a number of classrooms were unoccupied during testing. Test results appear in Tables 1-5.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in fourteen out of thirty-six areas surveyed, which can indicate a ventilation problem in these areas of the school. It is important to note that a large number of classrooms had open windows during the assessment, which can contribute to reduced carbon dioxide levels. It should also be noted that several classrooms had elevated carbon dioxide levels without occupancy, further indicating inadequate ventilation.

Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit (see Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were found deactivated in some areas (see Tables). Obstructions to airflow, such as paper and boxes stored on univent air diffusers and items in front of univent return vents, were also noted in classrooms (see Pictures 1 & 2). In order for univents to provide fresh air as designed, univent air diffusers and return vents must remain free of obstructions. Importantly, these units must remain activated while classrooms are occupied.

The mechanical exhaust ventilation system in classrooms in the 1958 wing consists of grated, wall-mounted exhaust vents. A number of exhaust vents were obstructed by tables, chairs, boxes and in some cases, ceiling tiles (see Picture 3). A dropped ceiling tile system was installed, which obstructed wall-mounted exhaust vents that are located near the ceilings. In a number of instances Mr. Mallioux has installed egg crate-type ceiling tiles, which allow airflow into the vent (see Picture 4). Exhaust ventilation in the 1968 wing is provided by unit exhaust ventilators (see Picture 5), many of which were off or drawing weakly. Without removal by the exhaust ventilation system, normally occurring environmental pollutants can build up and lead to indoor air complaints.

Ventilation for modular classrooms is provided by two air handling units (AHUs) located on the exterior wall of each classroom. Fresh air is distributed to classrooms via ductwork connected to ceiling-mounted air diffusers. Return vents draw air back to the units through wall or ceiling-mounted grilles. Thermostats control each heating, ventilating and air conditioning (HVAC) system. In modular classrooms, thermostats have fan settings of "on" and "automatic". Thermostats were set to the "automatic" setting in both of the modular rooms surveyed during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once a preset temperature is measured by the thermostat, the HVAC system is deactivated. Therefore no mechanical ventilation is provided until the thermostat re-activates the system.

In order to have proper ventilation with a mechanical supply and exhaust system, these systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. According to school officials, the date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix I.

Temperature readings were within a range of 70° F to 77° F, which was within the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained between 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the building ranged from 61 to 75 percent, which was above the BEHA recommended comfort range in some areas. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. With the combination of inactive ventilation systems and open exterior doors and windows, relative humidity levels can become elevated indoors. While temperature is mainly a comfort issue, relative humidity in excess of 70% can provide an environment for mold and fungal growth (ASHRAE, 1989).

Of note is that relative humidity measured indoors exceeded outdoor measurements (range +1-15 percent). The increase in relative humidity can indicate that the exhaust system is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration) or that no mechanical means of exhaust ventilation exists. Moisture removal is important since the sensation of heat conditions increases as relative humidity increases. As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several classrooms contained a number of plants. Plant soil and drip pans can serve as sources of mold growth. Plants should also be located away from univents and exhaust ventilation to prevent aerosolization of dirt, pollen or mold.

A few classrooms had water-damaged ceiling tiles which can indicate leaks from either the roof or plumbing system (see Picture 6). Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired.

Caulking was missing/damaged in the east side of the building. Water penetration through window frames can lead to mold growth under certain conditions. Repairs of window leaks are necessary to prevent further water penetration. Repeated water damage can result in mold colonization of window frames, curtains and items stored on windowsills. School officials reported that the school is undergoing three phases of window replacement, with the replacement of east-side windows as the final phase.

Modular Classrooms

Modular classrooms were examined. Guidance concerning prevention of mold growth was provided by BEHA to the North Andover School Department in relation to a different school facility in March 2002. According to this guidance, the following general improvements can be made to avoid microbial growth within these structures:

1. Use of sloped roof with properly installed gutter and downspout system to drain rainwater.
2. Sitting the structure on a well-drained surface.
3. Surface run-off should be directed away from the structure.
4. The crawlspace under the structure should be well ventilated.
5. Check all caulking and/or flashing around windows and service posts, especially after moving a structure.
6. Maintain ventilation according to American Society for Heating, Refrigerating and Air-conditioning Engineers (Stewart, B., 2002).

Using these guidelines as evaluation points, an analysis of modular units was conducted:

The exterior walls of the modular units appeared to be intact and drainage adequate. Two of the three modular classrooms are not equipped with a complete gutter/downspout system (see Pictures 7 & 8), which can allow rainwater to pool on the ground at the base of the building or against exterior walls. The freezing and thawing action of water during winter months can create cracks and fissures in the foundation. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other Concerns

Several other conditions that can potentially affect indoor air quality were also identified. Accumulated chalk dust and dry erase board particulate was noted in several classrooms. A few rooms had missing and/or dislodged ceiling tiles. Missing/dislodged ceiling tiles can provide a pathway for the movement of drafts, dusts and particulate matter between rooms and floors. Chalk dust and dry erase board particulates can be easily aerosolized and serve as eye and respiratory irritants. In addition, materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can also be irritating to the eyes, nose and throat.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provide a source for dusts to accumulate. These items, (e.g., papers, folders, boxes, etc.) also make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Of particular note are items hanging from ceiling tiles (see Picture 9). As discussed, the movement or damage to ceiling tiles can release accumulated dirt, dust and particulates that accumulate in the ceiling plenum into occupied areas.

Cleaning products were found on counter tops in classrooms. Cleaning products contain chemicals (such as bleach or ammonia-related compounds), which can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

The book room contains a lamination machine and photocopiers (see Picture 10). No local exhaust ventilation was identified in this area. Lamination machines give off odors. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992).

A number of exhaust vents in classrooms, restrooms and in the all-purpose room were noted with accumulated dust. If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that can be a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gassing volatile organic compounds (VOCs). Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1998).

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate *continuously* during periods of school occupancy independent of classroom thermostat control. Consider setting thermostat controls in modular classrooms to the fan "on" position to provide constant supply and exhaust ventilation during periods of occupancy.
2. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Operate fresh air supply univents while classrooms are occupied. Consider consulting a heating,

ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers school-wide.

3. Remove all blockages from univents and exhaust vents. Continue with plans to install egg crate-type ceiling tiles (as shown in Picture 4), where exhaust vents are obstructed.
4. Consider having the ventilation systems balanced by an HVAC engineering firm in accordance with (SMACNA, 1994).
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
6. Replace any remaining water-stained ceiling tiles and building materials. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
7. Continue with plans to replace windows in the east side of the building.
8. Ensure plants are equipped with drip pans and avoid over watering. Examine drip pans for mold growth and disinfect areas of water leaks with an appropriate antimicrobial where necessary.
9. Consider installing complete gutters/downspout systems to modular classrooms to direct rainwater away from the building.
10. Store cleaning products properly and out of reach of students.

11. Replace missing/damaged ceiling tiles. Refrain from hanging objects from ceiling tile system.

12. Clean chalkboards and trays regularly to avoid the build-up of excessive chalk dust.

13. Consider installing local exhaust ventilation in faculty workrooms to remove excess heat and odors from photocopier and lamination machine use.

14. Clean blades of portable fans and exhaust vents periodically of accumulated dust.

15. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

16. Discontinue the use of tennis balls on chairs to prevent latex dust generation.

References

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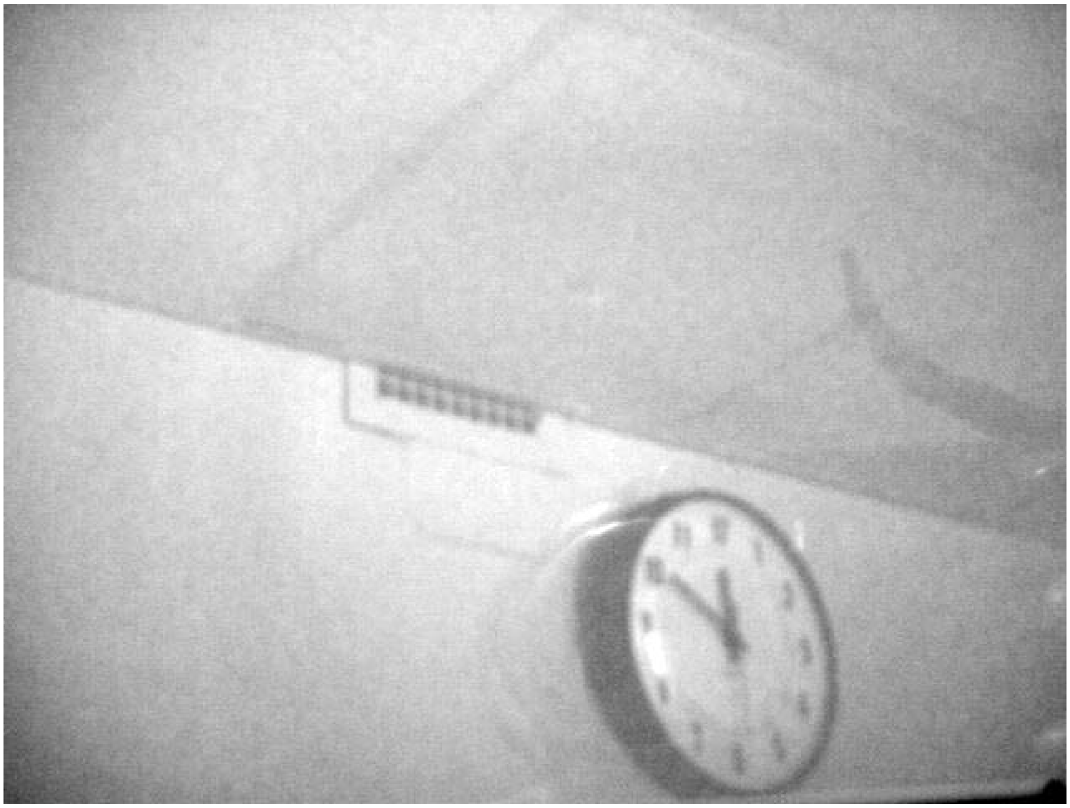
Picture 1

Univent Return Vent Obstructed by Items Taped to Front of Unit

Picture 2

Bookcases and Carts Placed around Univent Obstructing Airflow

Picture 3



Wall-Mounted Exhaust Vent Obstructed by Dropped Ceiling Tile System

Picture 4

Egg Crate-Type Ceiling Tile

Picture 5

Unit Exhaust Ventilator

Picture 6

Water Damaged Ceiling Tiles

Picture 7

Modular Classroom Unit, Note Gutter Installed over Entrance Only

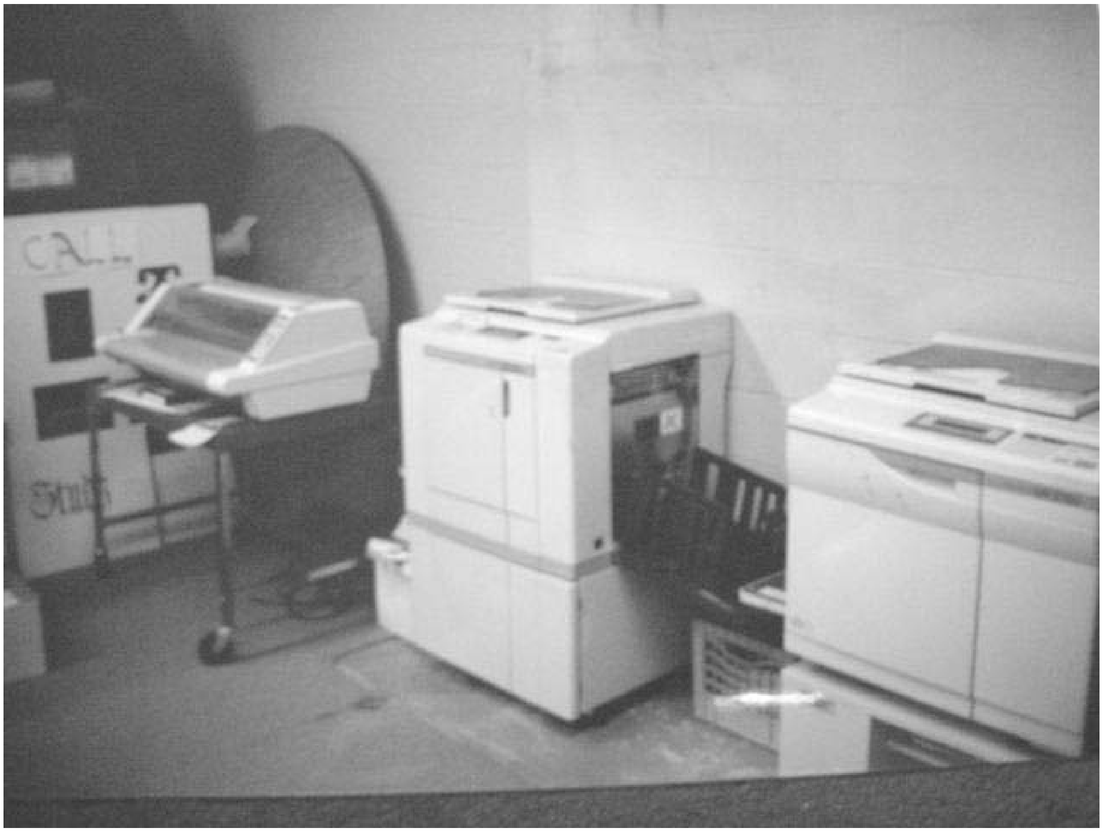
Picture 8

Modular Classroom, Note Lack of Gutter/Downspouts

Picture 9

Items Hanging From Ceiling Tiles System in Classroom

Picture 10



Lamination Machine and Photocopiers in Bookroom

TABLE 1

Indoor Air Test Results – Franklin Elementary School, North Andover, MA – June 6, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	432	70	60					Moderate-heavy rainfall
2D (Modular)	1647	74	68	1	Yes	Yes	Yes	21 occupants gone ~25 mins., thermostat fan on “auto”, ventilation off
2T	1861	77	61	19	Yes	Yes	Yes	Fan on “auto”
1C	863	74	67	1	Yes	Yes	Yes	Exhaust partially blocked, items on univent, items hanging from CT, spray cleaner under sink, dust accumulation on fan, door open
2H	1295	74	69	1	Yes	Yes	Yes	Univent off-requested by occupant, 17 occupants gone ~20 mins., cardboard boxes under sink, items on univent, exhaust vent blocked by table, door open
1F	682	74	69	0	Yes	Yes	Yes	Exhaust vent by computer table, univent return blocked by paper, window and door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Franklin Elementary School, North Andover, MA – June 6, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Art Room	520	72	69	1	Yes	Yes	Yes	Univent blocked by cart, exhaust vent partially blocked, fans operating, 2 water-damaged CT, window open
1H	698	71	71	16	Yes	Yes	Yes	Exhaust vent partially blocked, cleaning product on sink, door open
Toomey/Nassor	592	73	71	1	Yes	Yes	Yes	Window open
Principal's Office	551	71	69	1	Yes	No	Yes	Exhaust vent partially blocked by drop-ceiling, dooropen
Cafeteria	765	73	75	~100	Yes	Yes	Yes	Ventilation system deactivated due to mechanical problems
Book Room	703	74	69	0	No	Yes	No	3 water-damaged CT, damaged window caulking, 2 photocopiers, 1 lamination machine, passive intake, no mechanical exhaust
5Z	1263	75	71	16	Yes	Yes	Yes	Door open, chalk dust, rusted window frame, univent partially blocked, unit exhaust ventilator-off cycle, cleaning product on sink

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TABLE 3

Indoor Air Test Results – Franklin Elementary School, North Andover, MA – June 6, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Library	863	75	66	0	Yes	Yes	Yes	AHU, large group recently left
5L	1110	76	68	21	Yes	Yes	Yes	Items on/in front of univent, unit exhaust ventilator-off cycle, spray cleaning product on sink, door open
5M	1083	75	66	21	Yes	Yes	Yes	Items on/in front of univent, unit exhaust ventilator-off
LC3	603	75	63	4	Yes	Yes	Yes	Items on univent, items blocking exhaust, door open
14A	623	74	63	0	Yes	No	Yes	Univent off-return blocked
14B	524	72	59	0	Yes	No	Yes	Univent off, tennis balls/chair stops, window open
15	514	71	61	0	Yes	Yes	Yes	4 water-damaged CT, water-damaged CT in hallway
Gym	544	70	62	~40	Yes	Yes	Yes	3 broken/dislodged CT, exterior doors open, ceiling-mounted univent
O'Neill	841	73	70	0	No	Yes	Yes	Passive intake, dust accumulation on exhaust vents, chalk dust

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TABLE 4

Indoor Air Test Results – Franklin Elementary School, North Andover, MA – June 6, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
4K	839	72	67	0	No	Yes	Yes	Exhaust-off cycle, 1 water-damaged CT
4U	600	71	62	21	Yes	Yes	Yes	1 water-damaged CT, window open
4A	763	72	63	20	Yes	Yes	Yes	Univent obstructed by desk configuration
3M	1009	73	65	25	Yes	Yes	Yes	Items on univent, 2 water-damaged CT, cleaning product on sink, window open
3F	645	71	61	22	Yes	Yes	Yes	Items on univent, window open
Computer Lab	893	73	66	0	No	Yes	Yes	Items on univent, window open
3B	803	78	63	1	Yes	Yes	Yes	~22 occupants gone ,5 mins., items on univent, 3 water-damaged CT, 1 dislodged CT, window open
Boy's Restroom					Yes	No	Yes	Accumulated dust on exhaust vent
MacFarlan/Angelo	619	73	73	1	Yes	Yes	Yes	Window and door open, cleaning product under sink, paper towels

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Relative Humidity -	40 - 60%

TABLE 5

Indoor Air Test Results – Franklin Elementary School, North Andover, MA – June 6, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Nurse's Office	779	73	69	1	Yes	Yes	Yes	Univent off-dirt/dust build up in unit, exhaust vent blocked by open door, exhaust vent in restroom covered by drop-ceiling
(Modular) 24	714	72	56	0	Yes	Yes	Yes	Water-damaged CT outside door, thermostat fan on "auto"
22	975	72	69	1	Yes	Yes	Yes	Unit exhaust ventilator-off, 1 out of 2 univents on, 1 water-damaged CT, window open
22-restroom					No	Yes	Yes	No draw from exhaust vent, stick-up style air-freshener
1	661	72	70	4	Yes	Yes	Yes	Missing CT-due to roof leak, window open
Speech	642	72	70	0	Yes	No	Yes	No draw from exhaust vent
9	501	72	70	0	Yes	Yes	Yes	No draw from exhaust vent, door open
Main Office	498	70	67	1	Yes	No	Yes	Window open

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